



--	--	--	--	--	--	--	--	--	--	--	--

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EPM2036 – CONTROL THEORY (RE / TE)

2 MARCH 2019
2:30 p.m - 4:30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages including cover page with 4 Questions only. Laplace Transform Table is included in Appendix.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

a) A system is described by the following differential equation.

$$y''(t) + 7y'(t) + 12y(t) = x'(t) + 2x(t)$$

$x(t)$ and $y(t)$ are the input and output respectively. Assuming zero initial conditions,

i. Find the transfer function $Y(s)/X(s)$.

[3 marks]

ii. Identify the finite pole(s) and zero(s) for the transfer function.

[2 marks]

iii. Determine the output response $y(t)$, given that the input $x(t)$ is a unit step input.

[5 marks]

iv. Prove the final value theorem with the output.

[2 marks]

b) Using Mason's rule, find the transfer function $C(s)/R(s)$ for the signal flow graph in Figure 1.

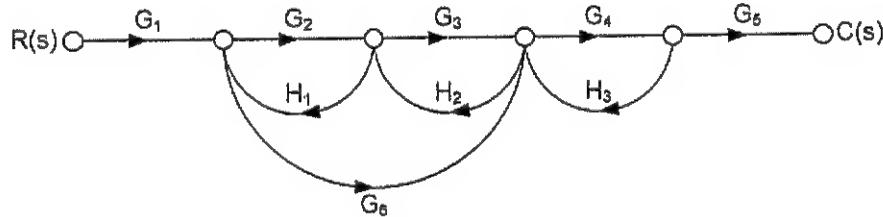


Figure 1

[13 marks]

Continued

Question 2

a) The open loop transfer function of a second order system is given as

$$G(s) = \frac{16}{s(s + 4)}$$

i. Prove that the step response of the system is underdamped.

[4 marks]

ii. Determine the oscillation frequency, ω

[3 marks]

iii. Determine the time t_{max} at which the maximum overshoot occurs.

[3 marks]

iv. Determine the overshoot.

[3 marks]

b) Given the characteristics equation as follows

$$s^4 + Ks^3 + 2s^2 + s + 1 = 0$$

Using Routh criterion, determine the range of K for stability.

[12 marks]

Continued

Question 3

The following is an open loop transfer function of a unity feedback system.

$$KG(s) = \frac{K(s+2)}{s(s+3)(s+4)}$$

- a) Determine all poles and zeros. [3 marks]
- b) Sketch the root loci of the system. [12 marks]
- c) If $K = 1$, draw the asymptotic magnitude bode plot for the function $G(s)$ on the semi log graph. [10 marks]

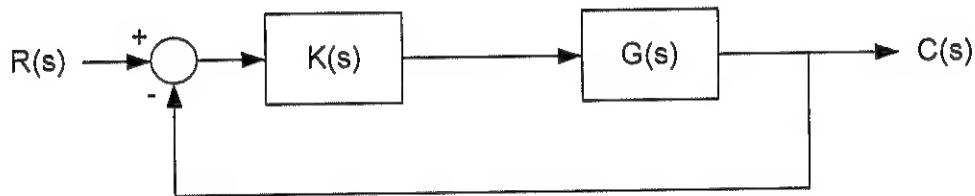
Continued

Question 4

A unity feedback system shown in Figure 2 has a plant transfer function $G(s)$. PI controller $K(s)$ is designed to control the plant.

$$G(s) = \frac{1}{(s+3)(s+4)}$$

$$K(s) = k_P + \frac{k_I}{s}$$

**Figure 2**

a) If the steady-state error for a unit ramp input must be no more than 0.06, determine k_I .

[9 marks]

b) Find the range of k_P for the system to be stable.

[9 marks]

c) Using the critical values for k_I and k_P , determine the closed-loop transfer function.

[7 marks]**Continued**

Appendix

Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $u(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \dots)$	$\frac{1}{s^n}$
$t^n \quad (n = 1, 2, 3, \dots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!} e^{-at} \quad (n = 1, 2, 3, \dots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \quad (n = 1, 2, 3, \dots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2}$
$\cos \omega t$	$\frac{s}{s^2 + \omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2 - \omega^2}$
$\cosh \omega t$	$\frac{s}{s^2 - \omega^2}$

Continued

$f(t)$	$F(s)$
$\frac{1}{a}(1 - e^{-at})$	$\frac{1}{s(s + a)}$
$\frac{1}{b-a}(e^{-at} - e^{-bt})$	$\frac{1}{(s + a)(s + b)}$
$\frac{1}{b-a}(be^{-bt} - ae^{-at})$	$\frac{s}{(s + a)(s + b)}$
$\frac{1}{ab} \left[1 + \frac{1}{a-b} (be^{-at} - ae^{-bt}) \right]$	$\frac{1}{s(s + a)(s + b)}$
$\frac{1}{a^2}(1 - e^{-at} - ate^{-at})$	$\frac{1}{s(s + a)^2}$
$\frac{1}{a^2}(at - 1 + e^{-at})$	$\frac{1}{s^2(s + a)}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s + a)^2 + \omega^2}$
$e^{-at} \cos \omega t$	$\frac{s + a}{(s + a)^2 + \omega^2}$
$\frac{\omega_n}{\sqrt{1 - \zeta^2}} e^{-\zeta \omega_n t} \sin \omega_n \sqrt{1 - \zeta^2} t$	$\frac{\omega_n^2}{s^2 + 2\zeta \omega_n s + \omega_n^2}$
$-\frac{1}{\sqrt{1 - \zeta^2}} e^{-\zeta \omega_n t} \sin(\omega_n \sqrt{1 - \zeta^2} t - \phi)$ $\phi = \tan^{-1} \frac{\sqrt{1 - \zeta^2}}{\zeta}$	$\frac{s}{s^2 + 2\zeta \omega_n s + \omega_n^2}$

Continued

$1 - \frac{1}{\sqrt{1 - \zeta^2}} e^{-\zeta \omega_n t} \sin(\omega_n \sqrt{1 - \zeta^2} t + \phi)$ $\phi = \tan^{-1} \frac{\sqrt{1 - \zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
$1 - \cos \omega t$	$\frac{\omega^2}{s(s^2 + \omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2 + \omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2 + \omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2 + \omega^2)^2}$
$t \cos \omega t$	$\frac{s^2 - \omega^2}{(s^2 + \omega^2)^2}$
$\frac{1}{\omega_2^2 - \omega_1^2} (\cos \omega_1 t - \cos \omega_2 t) (\omega_1^2 \neq \omega_2^2)$	$\frac{s}{(s^2 + \omega_1^2)(s^2 + \omega_2^2)}$
$\frac{1}{2\omega} (\sin \omega t + \omega t \cos \omega t)$	$\frac{s^2}{(s^2 + \omega^2)^2}$

End of Page